TRANS-126

KOLEBANIE IUZHNOI GRANITSY MNOGOLETNYKH L'DOV V MORE LAPTEVYKH

(Fluctuation of the Southern Boundary of Polar Ice in the Laptev Sea)

by

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PROBLEMY ARKTIKI I ANTARKTIKI, no.

(Problems of the Arctic and Antarctic)

No. 1, Pp. 5-10

LENINGRAD 1959

Translator: M. Slessers
M.O.: 15868-10
P.O.: 41246

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON 25, D. C.

1963

ABSTRACT

The interyearly and intrayearly (seasonal) displacements of the southern boundary of polar ice are discussed in connection with climatic and weather conditions in the area. The interrelation between the ice and weather conditions is analyzed on the basis of observational data concerning the phenomena so as to establish an accepta base for ice forecasting on the Great Northern Sea Route.

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Title: KOLEBANIE IUZHNOI GRANITSY MNOGOLETNYKH L'DOV V MORE LAPTEVYKH (Fluctuation of the Southern Boundary of Polar Ice in the Laptev Sea).

Source: PROBLEMY ARKTIKI I ANTARKTIKI (Problems of the Arctic and Antarctic). No. 1, Pp. 5-10. LENINGRAD 1959.

Language: Russian

Translator: M. Slessers

The translator acknowledges the helpful suggestions of C. W. Senior who read the manuscript.

FLUCTUATIONS OF THE SOUTHERN BOUNDARY OF POLAR ICE IN THE LAPTEV SEA

Of the numerous causes affecting changes in the iciness of Arctic seas, the interaction between the ice of marginal seas and that of the Arctic Basin is of great importance. In connection with the fact that during recent years the actual observations on the distribution of polar ice (arctic pack) in northern latitudes present a quantity of interesting data, a chance has arisen, though in the first approximation, to discuss the effect of periodic movement of old ice on the formation of ice conditions in the Arctic seas.

This study is based on the data of systematic observations on the boundaries of polar ice in various seasons during a 12 year period (from 1946 to 1958). Although the materials at hand are limited, they are of interest because they enable us for the time being to determine qualitatively the periods during which the inflow or outflow of polar ice predominate. One of the peculiar characteristics of synoptic conditions in the area of the Laptev Sea is a sharply pronounced interaction between the Atlantic-Arctic low and the anticyclonic regions over the Arctic Basin (the Polar anticyclone) and over the Asiatic Mainland (the Siberian anticyclone). According to V. Iu. Vize [1], the difference in geographical latitude of displacements of the Atlantic-Arctic low in the Laptev Sea area is about 10°. The other characteristic of the given sea is the fact that it represents a wide open gulf of the Arctic Basin, and therefore the exchange of ice between the Laptev Sea and the Arctic Basin is not encountered by any obstacles.

It can be assumed that the distribution of polar ice in the Laptev Sea is closely dependent on the periodic changes of the predominant ice drift in the Arctic Ocean. Evidently, considerable changes in the velocity and direction of ice transport in high latitudes are borne out by definite geographical variations in the location of the southern boundary of polar ice.

The observations of the last four years demonstrate that a very noticeable and continuous displacement of polar ice toward the south has taken place in the Laptev Sea. Thus, if in 1953-1954 the polar ice was found mainly in the area of latitude 83—84° N, in 1955 its southern boundary was in the parallel 82°, but in 1956 it was displaced southward and was observed in the area of latitude 78—79° N. The southernmost position of polar ice was reached in 1957, when a massive arctic pack was found in latitude 75—76° N. In its total complexity, the displacement of the boundary of old ice was about

1000 km southward, the mean speed being about 250 to 300 km a year. Up to the present time it was assumed that the southernmost boundary of polar ice in this sea is latitude 79—80° N (not individual penetration of polar ice but the zone of its prevalence is meant here). However, the ice conditions in 1957 showed that it is not at all so, and that in certain years the old ice reaches the southern latitudes of the sea.

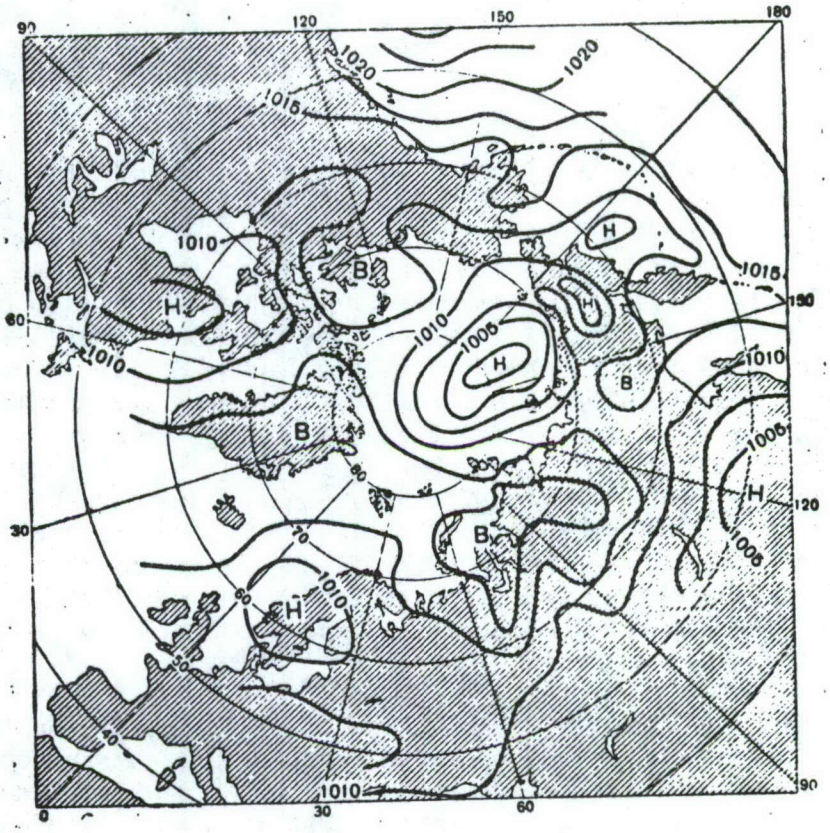

Fig. 1. Mean distribution of pressure in July-August 1957.

In 1957, only during four months (from June to October), did the polar ice of the western and central regions of the sea move southward for a distance of 420 km.

Such a southernmost boundary of polar ice in the navigational period did not occur during the observation period that is discussed here[1].

[1]Unfortunately, the data relative to the polar ice in the previous years either are entirely absent or are not dependable.

In the same year (1957) the total ice area in the sea was at a maximum, the anomaly of mean iciness during the navigational period reaching 35°/o of the standard amount (50°/o). The considerable southward displacement of the polar ice boundary in the year resulted from the development of unfavorable synoptic conditions, which were very stable during the entire navigational period (fig. 1). The presence of the center of cyclone to the northeast of Novosibirskiye ostrova (New Siberian Islands) for a long time period caused the predominance of northwesterly and northerly air currents not only over the Laptev Sea, but also over the entire western part of the Arctic Basin. They are very unfavorable for the Laptev Sea, insofar as they cause a stable ice drift toward the south. The appearance of individual cyclones from the west, which usually occur during the disappearance of ice, had an insignificant effect in 1957 and could not even /7
substantially diminish the southward movement of the entire ice stream. The positive effect of the cyclones was manifest only in that they furthered the formation of local transitory decreases in ice concentration along the poluostrov Taymyr (Taymyrskiy poluostrov).

There is no doubt that the unfavorable synoptic conditions in the summer were a decisive factor in the formation of such heavy ice conditions in the Laptev Sea. However, the appearance of polar ice in the part of the sea that was surveyed resulted from unfavorable hydrometeorological processes of not just one year. If we examine the data of preceding years (fig. 2) and follow the displacement of the southern boundary of polar ice, if only along two meridians, 125 and 140°, it appears that the southward movement of polar ice had a stable character. After the years characterized by great iciness (1948 and 1949), when the southern boundary of polar ice remained steadily in the latitudes 79—89° ✱, a considerable retreat of the boundary toward the north began. The facts indicated indirectly that in the subsequent period to 1953-1954 the inflow of ice prevailed in high latitudes. In 1953 the ice area of the Laptev Sea was 31°/o smaller than the average and the southern boundary of polar ice reached the northernmost position (beyond latitude 84°—84.5°).

Later, during the last five-year period, the boundary of polar ice was gradually moving southward, from year to year, and in 1957 the southernmost position of the ice was reached. The same consecutiveness occurred in the change of the sign and magnitude of iciness in

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✱ Sic! (Original paper probably should read 79—80°. Ed.).

the sea. The situation obviously indicates the relationship existing between the displacement of polar ice in high latitudes and the iciness of the Laptev Sea.

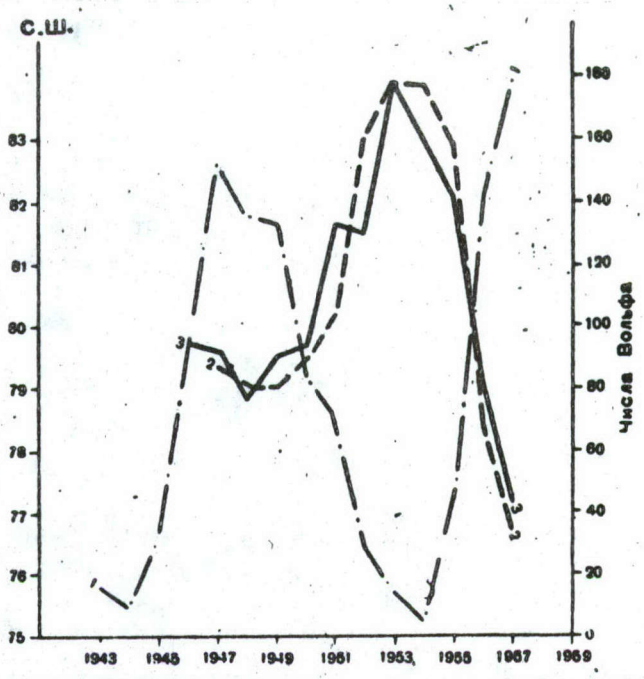

Fig. 2. The annual number of solar spots and interannual displacement of polar ice.

1 — Wolfe numbers; 2 — the boundary along meridian 125°; 3 — the boundary along meridian 140°.

Key:

Vertical line to the left - lat. N

Vertical line to the right - Wolfe numbers

In addition to the interannual movement, it is also interesting to examine the seasonal (intrayearly) movement of polar ice for shorter periods. For this purpose we constructed graphs (fig. 3) for half a year (from October to March), when intensive accumulation of ice takes place in the sea, and for another half year (from March to October), when the process of ice disintegration predominates in the sea. It /8

appeared (fig. 3) that from 1949 to 1953 in the cold half of the year (from October to March) the displacement of boundaries of polar ice from the south to the north prevailed, i.e. during the time an intensive outflow of ice from the sea took place. From 1954 to 1957 ice

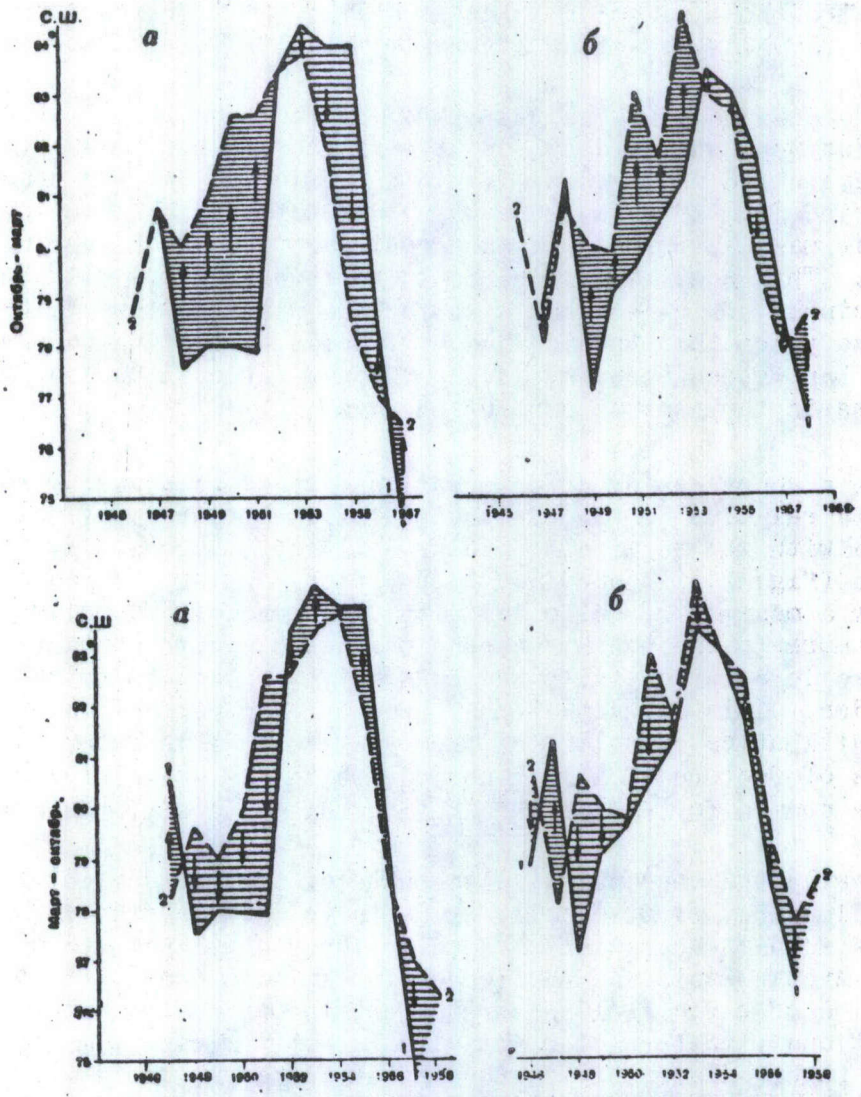

Fig. 3. Seasonal boundary displacements of polar ice.
а — along the meridian 125°; б — along the meridian 140°; 1 — the southern boundary in October; 2 — the southern boundary in March.

Key: Vertical line upper left - October-March
Vertical line lower left - March-October

in the same period moved southward, which indicated that the outflow of ice from the sea did not take place at all or that the process was diminished.

The data concerning the iciness of the Laptev Sea attest to the fact that after the minimum of iciness in 1953 the ice area began to increase gradually, reaching its maximum in 1957.

In the second half of the year (from March to October) the boundary of polar ice was usually displaced toward the south. However, in the central section of the sea a certain outflow of ice was observed during the period from 1952 to 1955, which demonstrated that the dynamic factor (air mass movement) played a positive role in the spring-summer season. This condition appeared to be favorable not only for the general iciness of the sea but also for the distribution of ice. It was in these years that the ice did not impede navigation on the sea route in the Laptev Sea because, during the navigational period, the arctic pack was in the central part of the sea.

Despite a short series of observations, it is interesting to compare the data relative to the fluctuation of the boundary of polar ice in the sea with the quotient of solar activity, expressed by the Wolfe numbers (fig. 2). According to the graph, during the years characterized by a maximum of solar activity, the boundary of polar ice is observed more to the south; whereas during the years characterized by a decrease in solar activity the boundary of polar ice retreats to higher latitudes. This shows that the tendency of preservation of anomaly in the distribution of polar ice from year to year is determined by changes of factors of a long period, which are associated with a cause that is common for all of the Arctic seas — namely, the solar activity.

Interyearly and seasonal displacements of the boundaries of polar ice are influenced, first of all, by definite baric systems, which are associated with essential changes in the general pattern of ice drift in the Arctic Basin and Arctic seas. Periodic changes in the transformation of baric fields over the Arctic Basin, the nature of whose connections with the solar activity is not yet clear, manifest themselves rather distinctly in the Laptev Sea area, where also considerable amplitude in the outflow of ice is observed. The "activity" of the Laptev Sea (this isespecially true of its deep region and the area of the "Sadko" Trench) in the overall ice drift of the Arctic Basin is confirmed by the considerable boundary displacements of polar ice, which are observed in the area and which denote also their substantial redistribution in high latitudes.

According to geographical location, the Laptev Sea occupies a central place among the Arctic seas and is located in a "boundary area" of three actively interrelated atmospheric centers: the North Atlantic low in the west, the Polar and Siberian anticyclones (high pressure areas) in the east. The intensity of interaction among these centers is rather clearly accounted for by the baric gradient in the cross section between mys Chelyuskin (Cape Ch.) and ostrov Kotel'nyy (K. Island), i.e. by a line perpendicular to the basic ice displacement toward the north. This fact was mentioned by D. B. Karelin when studying the question on the formation of ice conditions of the given sea [2]. An increase in the negative pressure difference on the mentioned line is a sign of intensified outflow of ice; a decrease in the difference, and still more a change of the sign to a positive value, is a sign of diminishing outflow of ice, and in certain years even a sign of their transfer from the north.

According to data listed in table 1, the replacement of a negative sign by a positive one coincides quite well with the character of displacement of the boundary of polar ice. The positive sign or a decrease in the sum of pressure differences attests to the formation of a baric system that is not favorable to ice drift, because such conditions are characterized by a southern position of the boundary of polar ice. Conversely, the increase in negative values of the difference in such years was usually accompanied by the appearance of old ice in high latitudes. This can be clearly seen from the observations carried out from 1954 to 1957. Thus, the following can be /10
stated: the interyearly displacement of the southern boundary of the polar ice is rather considerable in the Laptev Sea; in certain instances the displacement reaches 400 km and more in a year.

The displacement of the boundary of polar ice southward in the period of ice accumulation (from October to March) is associated with a decrease in the outflow of ice from the sea, and it usually leads to an increase in the iciness of the sea. According to numerous observations the phenomena of interyearly ice inertia in the sea have not been disclosed, and therefore the fact that it is in this area where the preservation of the sign, relative to the direction of interyearly displacements of polar ice boundaries (of the order of 3 to 4 years), is observed is of great interest for ice forecasting.

Because of a limited scope of materials, only a qualitative use of data as to the distribution of polar ice is available at the present time for the solution to the problem on the iciness that is to be

expected. However in the future, with increase of the material, the information could be utilized more widely for long-range prognostic computations.

Table 1

THE SUM OF PRESSURE DIFFERENCES ON THE LINE BETWEEN MYS CHELYUSKIN AND OSTROV KOTEL'NYY

Years	Sum of pressure differences by periods (mb)	
	October—March	March—October
1947	—25.8	—24.4
1948	—21.0	— 3.5
1949	—16.5	— 3.2
1950	—23.6	—10.4
1951	—20.8	—15.6
1952	—19.3	—11.4
1953	—16.3	—15.1
1954	—20.1	+ 4.2
1955	— 9.7	+14.5
1956	— 5.5	+ 5.4
1957	— 9.1	+13.5

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